Nuclear Shadowing and High-p_T Hadron Spectra in Relativistic Heavy Ion Collisions*

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Both the PHENIX [1] and STAR [2] collaborations have shown that production of hadrons with transverse momentum $p_T > 2$ GeV/c are suppressed compared to the pp reference spectrum convoluted with the number of binary collisions, $\langle \sigma_{NN}^{\rm in} T_{AA} \rangle$. The suppression is defined as

$$R_{AA}(p_T) = \frac{d\sigma_{AA}/dp_T}{\langle \sigma_{NN}^{\rm in} T_{AA} \rangle d\sigma_{pp}/dp_T} \qquad (1)$$

where $d\sigma_{AA}/dp_T$ and $d\sigma_{pp}/dp_T$ are the hadron p_T distributions in AA and pp collisions respectively and T_{AA} is the nuclear overlap function.

The data show that, for $p_T > 2$ GeV/c, $R_{AA}(p_T)$ is much less than 1. For charged hadrons (pions, protons and kaons), $R_{AA}(p_T) \approx 0.4$ [1, 2], while for π^0, $R_{AA}(p_T) \approx 0.3$ [1]. It appears that, for protons, there is very little suppression, with $R_{AA}(p_T) \approx 1.0$. A related ratio has been formed for central to peripheral collisions which produce low multiplicities, such as those in pp interactions. Similar values were found [1, 2]. The results at $\sqrt{S_{NN}} = 130$ GeV and 200 GeV are in agreement with each other.

One possible explanation for the strong suppression is parton energy loss. However, other, more conventional nuclear effects must also be considered. Gold nuclei have a different proton-to-mass ratio (Z/A) than the proton reference. The Z/A ratio is much less relevant for comparison of central and peripheral ion collisions. More importantly, the parton distributions in nuclei are known to be different from those in bare nucleons, a phenomenon known as shadowing. We give quantitative estimates of the effects of nuclear shadowing and isospin on R_{AA} for charged pions, kaons and protons separately.

We make a leading order (LO) calculation of minijet production to calculate the yield of high-p_T partons. We find that for $|y| \leq 1$, shadowing is only a few percent effect due to the restricted x regions, as the upper figure shows. The composition changes, with charged kaons slightly enhanced and protons slightly suppressed compared to charged pions. This difference is due to isospin. The fragmentation functions assume u and s quarks and antiquarks fragment identically to charged kaons so that at large p_T, charged kaon production is favored in AA collisions relative to pp. On the other hand, a u quark is twice as likely to produce a proton than a d quark so that proton production is favored in pp interactions. The isospin effect is larger than the nuclear modifications on kaons and protons for $p_T > 7.5$ GeV/c. The dominance of pion production by gluons and the assumption that u and d are equally likely to produce charged pions leads to a negligible isospin effect. Thus R_{AA} for pions is influenced only by the nuclear modifications.

Thus, nuclear shadowing cannot explain a significant fraction of the observed suppression of high-p_T particles at RHIC. With the EKS98 parameterization and the nuclear isospin, at midrapidities $1.0 < R_{AA} < 1.1$ for charged mesons and $R_{AA} \approx 1$ for protons. Without the restriction $|y| \leq 1$, shadowing and isospin have a bigger effect on R_{AA}, as shown in the lower figure.

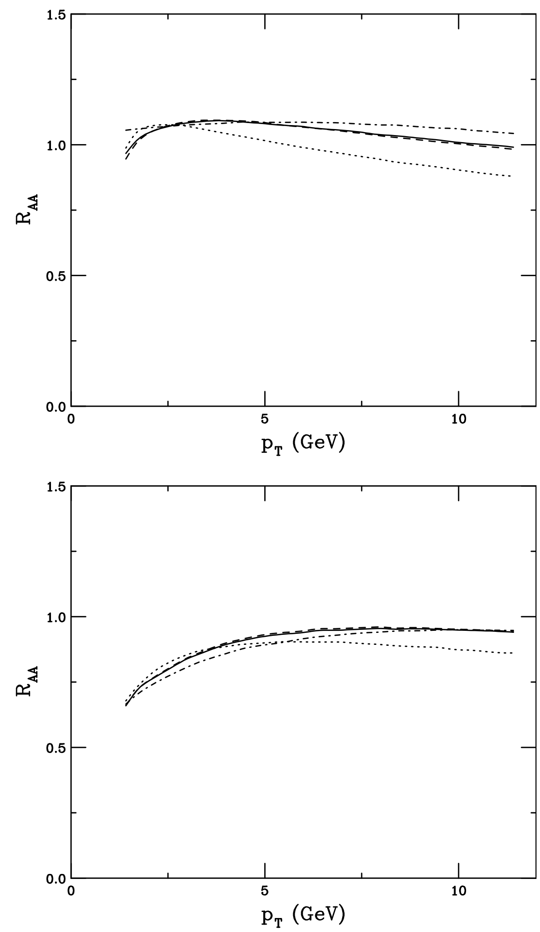

FIG. 1: R_{AA} for pions (dashed curve), kaons (dot-dashed curve), protons (dotted curve) and the average over all hadrons (solid line) for gold-gold collisions with $|y| \leq 1$ (upper plot) and integrated over all y (lower plot) at $\sqrt{S_{NN}} = 200$ GeV as a function of p_T.

* LBNL-52556; Phys. Rev. **C67** (2003) 047901.

[1] K. Adcox *et al.* (PHENIX Collab.), arXiv:nucl-ex/0207009; Phys. Rev. Lett. **88**, 022301 (2002); D. d'Enterria, arXiv:hep-ex/0209051; J. Jia, arXiv:nucl-ex/0209029.

[2] C. Adler *et al.* (STAR Collab.), Phys. Rev. Lett. **89**, 202301 (2002); J. L. Klay, arXiv:nucl-ex/0210026.